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1 **A framework for identifying and selecting long term adaptation policy directions for deltas**

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21

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24 *and Adaptation (DECCMA) project (IDRC 107642) under the Collaborative Adaptation Research*

25 *Initiative in Africa and Asia (CARIAA) programme with financial support from the UK Government's*

26 *Department for international Development (DFID) and the International Development Research*
27 *Centre (IDRC), Canada. The views expressed in this work are those of the creators and do not*
28 *necessarily represent those of DFID and IDRC or its Boards of Governors.*

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Abstract

Deltas are precarious environments experiencing significant biophysical, and socio-economic changes with the ebb and flow of seasons (including with floods and drought), with infrastructural developments (such as dikes and polders), with the movement of people, and as a result of climate and environmental variability and change. Decisions are being taken about the future of deltas and about the provision of adaptation investment to enable people and the environment to respond to the changing climate and related changes. The paper presents a framework to identify options for, and trade-offs between, long term adaptation strategies in deltas. Using a three step process, we: (1) identify current policy-led adaptations actions in deltas by conducting literature searches on current observable adaptations, potential transformational adaptations and government policy; (2) develop narratives of future adaptation policy directions that take into account investment cost of adaptation and the extent to which significant policy change/ political effort is required; and (3) explore trade-offs that occur within each policy direction using a subjective weighting process developed during a collaborative expert workshop. We conclude that the process of developing policy directions for adaptation can assist policy makers in scoping the spectrum of options that exist, while enabling them to consider their own willingness to make significant policy changes within the delta and to initiate transformative change.

73 1. Introduction

74 Deltas are dynamic, stressed and often densely populated environments. They are especially
75 vulnerable to the impacts of climate change and variability, including sea-level rise, erosion, land loss,
76 increased soil salinity, and changing storms { ADDIN EN.CITE { ADDIN EN.CITE.DATA }}. These factors
77 combined with subsidence and sediment starvation are rapidly changing the coastal landscape {
78 ADDIN EN.CITE { ADDIN EN.CITE.DATA }}. This has implications for deltaic populations who rely on
79 the economic activities and ecosystems services that deltas provide { ADDIN EN.CITE
80 <EndNote><Cite><Author>Ericson</Author><Year>2006</Year><RecNum>641</RecNum><DisplayText>(Ericson et al., 2006)</DisplayText><record><rec-number>641</rec-number><foreign-
81 keys><key app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">641</key></foreign-
82 keys><ref-type name="Journal Article">17</ref-type><contributors><authors><author>Ericson,
83 Jason P</author><author>Vörösmarty, Charles J</author><author>Dingman, S
84 Lawrence</author><author>Ward, Larry G</author><author>Meybeck,
85 Michel</author></authors></contributors><titles><title>Effective sea-level rise and deltas: causes
86 of change and human dimension implications</title><secondary-title>Global and Planetary
87 Change</secondary-title></titles><periodical><full-title>Global and Planetary Change</full-
88 title></periodical><pages>63-
89 82</pages><volume>50</volume><number>1</number><dates><year>2006</year></dates><isbn>
90 0921-8181</isbn><urls></urls></record></Cite></EndNote>}. Without adaptation measures to
91 address these multiple stresses, deltas could struggle to attain the Sustainable Development Goals
92 (SDGs) and become unsafe locations. Human interventions have a long history in deltas through
93 efforts to enhance livelihoods and reduce hazards. Engineered adaptation interventions, where they
94 have occurred, have arguably had a major impact on delta evolution { ADDIN EN.CITE
95 <EndNote><Cite><Author>Welch</Author><Year>2017</Year><RecNum>678</RecNum><DisplayText>(Welch et al., 2017)</DisplayText><record><rec-number>678</rec-number><foreign-keys><key

98 app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">678</key></foreign-keys><ref-type
99 name="Journal Article">17</ref-type><contributors><authors><author>Welch,
100 AC</author><author>Nicholls, RJ</author><author>Lázár,
101 AN</author></authors></contributors><titles><title>Evolving deltas: Coevolution with engineered
102 interventions</title><secondary-title>Elem Sci Anth</secondary-title></titles><periodical><full-
103 title>Elem Sci Anth</full-
104 title></periodical><volume>5</volume><dates><year>2017</year></dates><isbn>2325-
105 1026</isbn><urls></urls></record></Cite></EndNote>}. However, these adaptations have not been
106 systematically planned, assessed or documented to date. Consequently, there is a pressing need for
107 information about what deltaic communities and their governments can do to adapt. Drawing on
108 evidence of policy-led adaptations collected through a five year IDRC funded project ('Deltas,
109 Vulnerability & Climate Change: Migration and Adaptation' - DECCMA) this paper aims to provide
110 policy makers with insight into plausible adaptation policy directions in deltas. DECCMA's
111 geographical focus is on three deltas in Africa and Asia: the Volta in Ghana, the Mahanadi in India,
112 and the Ganges-Brahmaputra-Meghna (GBM) spanning India and Bangladesh (Figure 1). However,
113 this paper has a wider relevance, especially for large ecosystems, as we seek to generate a method
114 for understanding adaptation in complex social and physical environments.

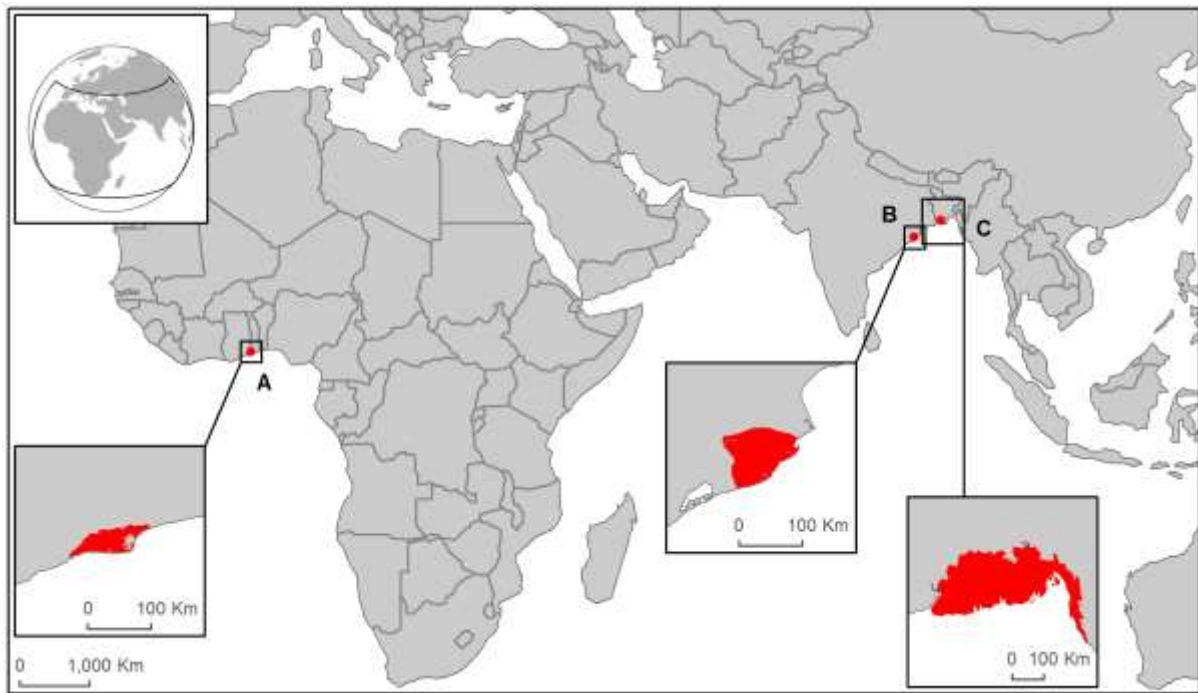


Figure 1: Map of the DECCMA study deltas (A: Volta Delta, Ghana; B: Mahanadi Delta, India; C: Ganges-Brahmaputra-Meghna (GBM), India and Bangladesh)

Adaptation policy is a newly emerging area for most countries where it is becoming an increasingly important challenge to meet. Adaptation is all the more pertinent in the context of the Paris Agreement 2015, the global agreement to address climate change, adopted under the United Nations Framework Convention on Climate Change (UNFCCC). The Paris Agreement introduces an ‘ambition mechanism’ requiring countries to strengthen their commitments to adaptation and mitigation. Many countries are grappling with the possible contents of adaptation policy, and this is especially challenging in large interconnected and transboundary ecosystems, such as deltas, mountains or coasts, where adaptation policies do not exist. Using deltas as an example, we reflect on the challenges affecting large ecosystems, that often have both upstream and downstream areas, and that may span national or regional borders. The aim of this paper is therefore to explore long term adaptation policy choices for deltas. To do this we ask: (1) what adaptations are occurring in

deltas?; (2) what are possible future directions for adaptation policy?; and (3) what are the trade-offs associated with each policy direction?

This paper first reviews the theoretical literature on framing adaptation, and considers the key drivers underpinning adaptation policy development (section 2). Drawing on data collected by DECCMA researchers during literature searches, inventory analysis and policy analysis, we then outline the planned, policy-led adaptations that are currently occurring in deltas, as well as presenting a method to create and populate four discrete directions for adaptation policy, which considers the trade-offs between different aspects of adaptation (section 3). Section 4 describes specific adaptation actions in DECCMA's three deltas, in the context of the four directions for policy, which range from a minimum intervention approach to radical transformational adaptation.

2. Adaptation theory

Broadly defined, adaptation is "an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"

{ ADDIN EN.CITE <EndNote><Cite ExcludeAuth="1"><Author>Intergovernmental Panel on Climate Change (IPCC)</Author><Year>2007</Year><RecNum>679</RecNum><Prefix>IPCC`, </Prefix><DisplayText>(IPCC, 2007)</DisplayText><record><rec-number>679</rec-number><foreign-keys><key app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">679</key></foreign-keys><ref-type name="Book">6</ref-type><contributors><authors><author>Intergovernmental Panel on Climate Change (IPCC),</author></authors><secondary-authors><author>Parry, Martin L</author><author>Canziani, OF</author><author>Palutikof, Jean P</author><author>van der Linden, Paul J</author><author>Hanson, Clair E</author></secondary-authors></contributors><titles><title>Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,

2007</title></titles><dates><year>2007</year></dates><urls></urls></record></Cite></EndNote> }.

However, debates surrounding more precise definitions as well as the content of adaptation continue unabated adding to the perceived complexity of understanding adaptation { ADDIN EN.CITE <EndNote><Cite><Author>Lesnikowski</Author><Year>2016</Year><RecNum>5560</RecNum><DisplayText>(Lesnikowski et al., 2016)</DisplayText><record><rec-number>5560</rec-number><foreign-keys><key app="EN" db-id="552vavf0m5009dezrviv5909wperzvdf9at9" timestamp="1510134691">5560</key></foreign-keys><ref-type name="Journal Article">17</ref-type><contributors><authors><author>Lesnikowski, Alexandra</author><author>Ford, James</author><author>Biesbroek, Robbert</author><author>Berrang-Ford, Lea</author><author>Heymann, S. Jody</author></authors></contributors><titles><title>National-level progress on adaptation</title><secondary-title>Nature Clim. Change</secondary-title></titles><periodical><full-title>Nature Clim. Change</full-title></periodical><pages>261-264</pages><volume>6</volume><number>3</number><dates><year>2016</year><pub-dates><date>03//print</date></pub-dates></dates><publisher>Nature Publishing Group</publisher><isbn>1758-678X</isbn><work-type>Letter</work-type><urls><related-urls><url><http://dx.doi.org/10.1038/nclimate2863></url></related-urls></urls><electronic-resource-num>10.1038/nclimate2863http://www.nature.com/nclimate/journal/v6/n3/abs/nclimate2863.html#supplementary-information</electronic-resource-num></record></Cite></EndNote> }.

Despite the lack of consensus in answering questions about the relationship between adaptation and other variables e.g. coping and adapting, or adaptation and development, progress has been made on agreeing its broad aims. It is generally agreed that adaptation aims to: (1) address drivers of vulnerability; (2) reduce disaster risk (DRR); and, (3) build landscape/ecosystem resilience { ADDIN EN.CITE { ADDIN EN.CITE.DATA } }. These three broad aims allow a simpler categorisation of adaptation options and an easier communication to stakeholders. We are thus developing and organising our policy adaptation scenarios around these categories.

179 Well-developed theoretical constructs already exist to allow us to explore the three aims of
180 adaptation in more detail. To better understand the first aim, addressing the drivers of vulnerability,
181 the sustainable livelihoods approach (SLA) builds on decades of work on entitlements and
182 endowments. It has been widely used to document poverty and wellbeing in the context of shocks
183 and stresses { ADDIN EN.CITE
184 <EndNote><Cite><Author>Chambers</Author><Year>1992</Year><RecNum>2772</RecNum><DisplayText>(Carney, 1998; Chambers and Conway, 1992)</DisplayText><record><rec-number>2772</rec-number><foreign-keys><key app="EN" db-id="552vavf0m5009dezrviv5909wperzvd9at9" timestamp="1343720948">2772</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Chambers, R.</author><author>Conway, G. </author></authors></contributors><titles><title>Sustainable rural livelihoods: practical concepts for the 21st century</title></titles><dates><year>1992</year></dates><pub-location>Brighton</pub-location><publisher>Institute of Development Studies.</publisher><urls></urls></record></Cite><Cite><Author>Carney</Author><Year>1998</Year><RecNum>873</RecNum><record><rec-number>873</rec-number><foreign-keys><key app="EN" db-id="552vavf0m5009dezrviv5909wperzvd9at9" timestamp="1334223875">873</key></foreign-keys><ref-type name="Edited Book">28</ref-type><contributors><authors><author>Diana Carney</author></authors><secondary-authors><author>DFID Natural Resources Department,</author></secondary-authors></contributors><titles><title>Sustainable rural livelihoods: What contributions can we make?</title></titles><dates><year>1998</year></dates><pub-location>London</pub-location><publisher>Department for International Development (DfID)</publisher><urls></urls></record></Cite></EndNote>}. The SLA offers a visual and practical framework to categorise adaptations around the different forms of capitals that are used to generate income and support livelihoods { ADDIN EN.CITE

205 <EndNote><Cite><Author>DfID</Author><Year>1999</Year><RecNum>599</RecNum><DisplayText
 206 >(DfID, 1999)</DisplayText><record><rec-number>599</rec-number><foreign-keys><key app="EN"
 207 db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">599</key></foreign-keys><ref-type
 208 name="Journal Article">17</ref-type><contributors><authors><author>DfID,
 209 UK</author></authors></contributors><titles><title>Sustainable livelihoods guidance
 210 sheets</title><secondary-title>London: DFID</secondary-title></titles><periodical><full-
 211 title>London: DFID</full-
 212 title></periodical><dates><year>1999</year></dates><urls></urls></record></Cite></EndNote>}.
 213 The five capitals used in the SLA relate to people's stocks of / access to: i) the natural environment
 214 (*natural capital*); ii) health, education and physical wellbeing (*human capital*); iii) financial resources
 215 (*financial capital*); iv) physical assets and infrastructure, such as houses, cars, phones (*physical*
 216 *capital*); and v) access to social networks and community support (*social capital*).
 217 The Hyogo and Sendai Frameworks { ADDIN EN.CITE
 218 <EndNote><Cite><Author>UNISDR</Author><Year>2005</Year><RecNum>600</RecNum><Display
 219 Text>(UNISDR, 2005; UNISDR, 2015)</DisplayText><record><rec-number>600</rec-
 220 number><foreign-keys><key app="EN" db-
 221 id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">600</key></foreign-keys><ref-type name="Web
 222 Page">12</ref-
 223 type><contributors><authors><author>UNISDR</author></authors></contributors><titles><title>H
 224 yogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to
 225 Disasters. 22 (International Strategy for Disaster Reduction
 226 www.unisdr.org)</title></titles><dates><year>2005</year></dates><pub-location>Geneva</pub-
 227 location><urls></urls></record></Cite><Cite><Author>UNISDR</Author><Year>2015</Year><RecN
 228 um>601</RecNum><record><rec-number>601</rec-number><foreign-keys><key app="EN" db-
 229 id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">601</key></foreign-keys><ref-type name="Web
 230 Page">12</ref-

231 type<<contributors><authors><author>UNISDR</author></authors></contributors><titles><title>Se
232 ndai Framework for Disaster Risk Reduction 2015-2030. 37 (International Strategy for Disaster
233 Reduction www.unisdr.org)</title></titles><dates><year>2015</year></dates><pub-
234 location>Geneva</pub-location><urls></urls></record></Cite></EndNote>} categorise actions that
235 address the second aim of adaptation, DRR. These frameworks respond to decades of research into
236 DRR that finds that disasters do not happen on their own – they are created through people’s
237 susceptibility and exposure to hazards { ADDIN EN.CITE <EndNote><Cite><Author>World
238 Bank</Author><Year>2010</Year><RecNum>4938</RecNum><DisplayText>(Pelling, 2001; World
239 Bank and United Nations, 2010)</DisplayText><record><rec-number>4938</rec-number><foreign-
240 keys><key app="EN" db-id="552vavf0m5009dezrviv5909wperzvd9at9"
241 timestamp="1343720960">4938</key></foreign-keys><ref-type name="Report">27</ref-
242 type><contributors><authors><author>World Bank,</author><author>United
243 Nations,</author></authors></contributors><titles><title>Natural Hazards, UnNatural Disasters.
244 The Economics of Effective
245 Prevention</title></titles><pages>254</pages><dates><year>2010</year></dates><pub-
246 location>Washington D.C.</pub-location><publisher>The International Bank for Reconstruction and
247 Development / The World
248 Bank</publisher><urls></urls></record></Cite><Cite><Author>Pelling</Author><Year>2001</Year>
249 <RecNum>4206</RecNum><record><rec-number>4206</rec-number><foreign-keys><key
250 app="EN" db-id="552vavf0m5009dezrviv5909wperzvd9at9"
251 timestamp="1343720956">4206</key></foreign-keys><ref-type name="Book Section">5</ref-
252 type><contributors><authors><author>Pelling, M. </author></authors><secondary-
253 authors><author>Castree, N.</author><author>Braun, B.</author></secondary-
254 authors></contributors><titles><title>Natural Disasters?</title><secondary-title>Social
255 Nature</secondary-title></titles><pages>170-
256 188</pages><dates><year>2001</year></dates><pub-location>Oxford</pub-

location><publisher>Blackwell</publisher><urls></urls></record></Cite></EndNote>}. The frameworks acknowledge that susceptibility and exposure arises from a lack of action in four time steps: i) *long term risk mitigation*, such as managing land or infrastructure to reduce risk; ii) *hazard preparedness*, i.e. preparing for specific hazards, for example through developing risk management plans; iii) *response*, timely action taken immediately before, during or immediately after a hazardous event, e.g. evacuation or going to a shelter; and iv) *recovery and rehabilitation*, i.e. returning to normality after a disaster, such as search and rescue, or rebuilding post disaster.

A third framework, the Millennium Ecosystem Assessment { ADDIN EN.CITE <EndNote><Cite ExcludeAuth="1"><Author>MEA (Millennium Ecosystem Assessment)</Author><Year>2005</Year><RecNum>602</RecNum><Prefix>MEA </Prefix><DisplayText>(MEA 2005)</DisplayText><record><rec-number>602</rec-number><foreign-keys><key app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">602</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>MEA (Millennium Ecosystem Assessment),</author></authors></contributors><titles><title>Millennium ecosystem assessment</title><secondary-title>Ecosystems and human wellbeing: a framework for assessment Washington, DC: Island Press</secondary-title></titles><periodical><full-title>Ecosystems and human wellbeing: a framework for assessment Washington, DC: Island Press</full-title></periodical><dates><year>2005</year></dates><urls></urls></record></Cite></EndNote>}, categorises actions that address the third aim of adaptation, building social-ecological resilience. The MEA recognises the value of ecosystems and the services that they provide. Following CGIAR { ADDIN EN.CITE <EndNote><Cite ExcludeAuth="1"><Author>CGIAR Research Program on Water Land and Ecosystems (WLE)</Author><Year>2014</Year><RecNum>595</RecNum><DisplayText>(2014)</DisplayText><record><rec-number>595</rec-number><foreign-keys><key app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">595</key></foreign-keys><ref-type

283 name="Report">27</ref-type><contributors><authors><author>CGIAR Research Program on Water
 284 Land and Ecosystems (WLE),</author></authors></contributors><titles><title>Ecosystem services
 285 and resilience framework. </title><secondary-title>Colombo, Sri Lanka: International Water
 286 Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE). 46p.
 287 doi: 10.5337/2014.229</secondary-
 288 title></titles><dates><year>2014</year></dates><urls></urls></record></Cite></EndNote>} and {
 289 ADDIN EN.CITE <EndNote><Cite
 290 AuthorYear="1"><Author>Walker</Author><Year>2012</Year><RecNum>604</RecNum><DisplayT
 291 ext>Walker and Salt (2012</DisplayText><record><rec-number>604</rec-number><foreign-
 292 keys><key app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">604</key></foreign-
 293 keys><ref-type name="Book">6</ref-type><contributors><authors><author>Walker,
 294 Brian</author><author>Salt, David</author></authors></contributors><titles><title>Resilience
 295 thinking: sustaining ecosystems and people in a changing
 296 world</title></titles><dates><year>2012</year></dates><publisher>Island
 297 Press</publisher><isbn>1597266221</isbn><urls></urls></record></Cite></EndNote>}} we define
 298 ecosystems services as the combined actions of natural processes that perform functions of value to
 299 society. Since the MEA, ecosystems are broadly recognised as delivering four main types of services:
 300 i) provision of food, water, building materials and protection of direct use to people (*provisioning*
 301 *services*); ii) maintenance of a diversity of species (e.g. bee and bird populations to fertilise plants) to
 302 support other ecosystems (*habitat services*); iii) maintenance of healthy planetary systems e.g. trees
 303 to regulate the climate and air quality (*regulating services*); and iv) aesthetic, spiritual, mental health,
 304 and cognitive development services (*cultural services*). By using the MEA in conjunction with the SLA,
 305 the interrelationships between natural resources and human wellbeing are recognised. As such, this
 306 approach addresses criticisms of the SLA that relate to the concept of 'natural capital', notably, that
 307 by suggesting ecological processes are a form of capital, trading them for another form of capital, for
 308 monetary or other gain, is without consequence { ADDIN EN.CITE

309 <EndNote><Cite><Author>Sneddon</Author><Year>2000</Year><RecNum>635</RecNum><Display
310 Text>(Sneddon, 2000)</DisplayText><record><rec-number>635</rec-number><foreign-keys><key
311 app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">635</key></foreign-keys><ref-type
312 name="Journal Article">17</ref-type><contributors><authors><author>Christopher S.
313 Sneddon</author></authors></contributors><titles><title>'Sustainability' in ecological economics,
314 ecology and livelihoods: a review</title><secondary-title>Progress in Human
315 Geography</secondary-title></titles><periodical><full-title>Progress in Human Geography</full-
316 title></periodical><pages>521-
317 549</pages><volume>24</volume><number>4</number><keywords><keyword>ecological
318 economics,ecology,sustainability,sustainable development,sustainable
319 livelihoods</keyword></keywords><dates><year>2000</year></dates><urls><related-
320 urls><url><http://journals.sagepub.com/doi/abs/10.1191/030913200100189076></url></related-
321 urls></urls><electronic-resource-num>10.1191/030913200100189076</electronic-resource-
322 num></record></Cite></EndNote>.

323 Collectively, these three theoretical frameworks allow us to consider adaptation options at multiple
324 spatial scales, across multiple environments (from human to natural), and at multiple administrative
325 scales (household to national). To allow us to identify and document adaptations we use all three
326 frameworks (Figure 2), recognising 13 classes of adaptation. Although we document adaptations
327 using deltas as an example, these classes of adaptation could apply anywhere.

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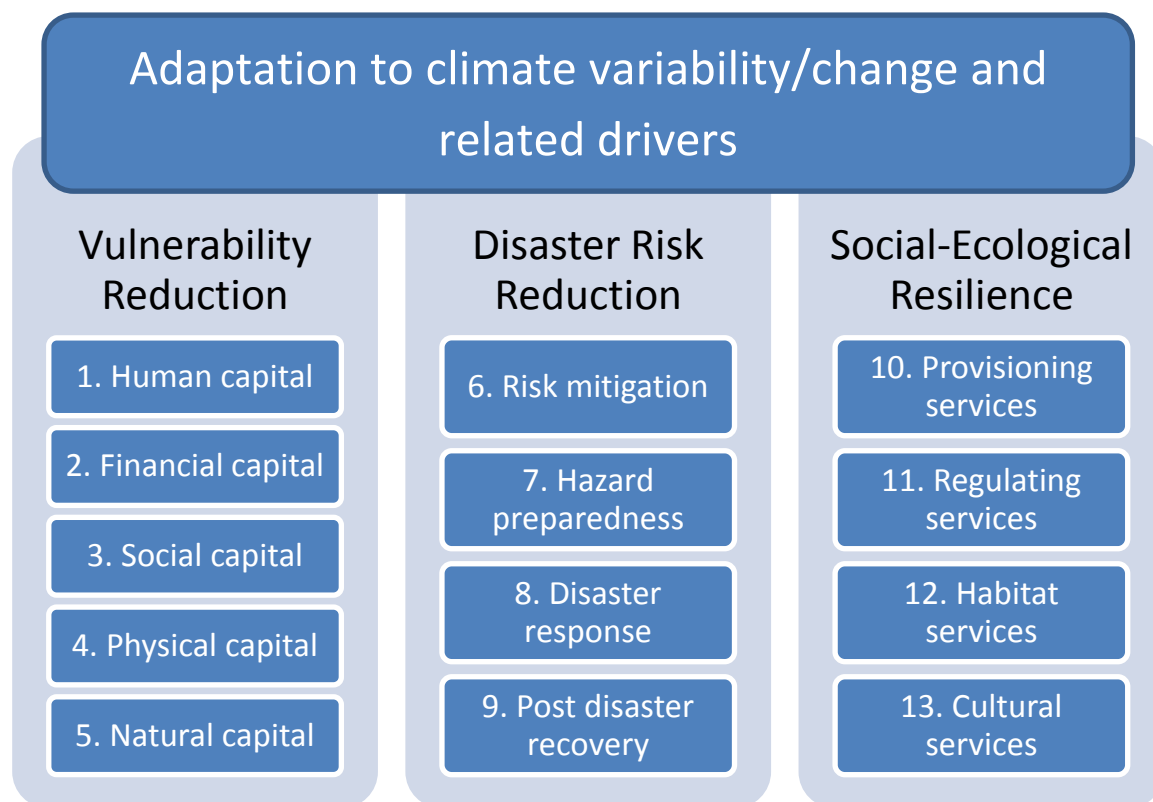


Figure 2: Classes of adaptation

As with any typology, there are inevitably overlaps between categories. To address this issue, we have slightly modified the focus of some of the 13 classes, which are outlined in greater detail in Table 1. For example, to address areas of potential duplication between ‘natural capital’ and ‘provisioning services’, we include ‘natural capital’ adaptations only where the adaptation actively influences livelihoods and relates to land access and ownership. For example, natural capital adaptations may include land reclamation and redistribution (to the poor or other groups) or fishing zones with associated fishing rights. In contrast, adaptations included in ‘provisioning services’ relate to the production of goods and services by the land. These adaptations may include the use of climate tolerant crops or the provision of seed banks. The following section applies this framework to first identify current adaptation actions in deltas, and then to create directions for policy that explicitly show the trade-offs between the 13 different classes.

Broad objective of adaptation	Class of adaptation	Description of plausible adaptations
Addressing drivers of vulnerability	1. Financial Capital	Changes in flows of money and savings that households have available, including loans and insurance
	2. Human Capital	Changes in skills, health and ability to labour of members of a household
	3. Social Capital	Changes in networks, relationships and membership of groups that households can use
	4. Natural Capital	Changes in land ownership and access to natural resources and storage facilities
	5. Physical Capital	Changes in infrastructure and goods such as tools and equipment that households can use to increase productivity and non-productive assets of the households (e.g. house material)
Disaster Risk Reduction	6. Managing long term risk	Efforts to build physical and social infrastructure that mitigate the worst impacts of an event. These can be one off activities, for example, building a sea wall, cyclone shelters, or on-going initiatives, e.g. developing flood risk management plans or relocating communities.
	7. Preparedness	Efforts to ensure communities are ready to respond to an event. These activities take place cyclically, for example, ensuring sea walls are maintained, practicing evacuation drills, or testing early warning systems.
	8. Response	Efforts to ensure affected households, communities, business and services receive appropriate assistance during and immediately following an event, e.g. evacuation support, first aid medical supplies, emergency responders
	9. Post disaster recovery and rehabilitation	Efforts to ensure affected households, communities, business and services are able to rebuild following an event, e.g. rehousing, reconstruction, etc.
Landscape/ ecosystem resilience	10. Provisioning services	Changes in ecosystem goods, quality or productivity that can be directly consumed, such as food, water, raw materials (e.g. fibre, biofuel, ornamental items), but also adaptations that enhance these services such as the use of irrigation and fertiliser
	11. Regulating services	Changes in the services that keep the wider planetary systems (such as the atmosphere, cryosphere, oceans) functioning and include the regulation of climate, air, nutrient cycles and water flows; moderation of extreme events; treatment of waste – including water purification; preventing erosion; maintaining soil fertility; pollination; and biological controls, such as pests and diseases.
	12. Habitat services	Changes in the habitats that maintain the life cycles of species or maintain genetic diversity, through quality and quantity of suitable habitats. In turn, these habitats underpin the health of provisioning and regulating services.

	13. Cultural services	Changes in aesthetic, recreational and tourism, inspirational, spiritual, cognitive development and mental health services provided by ecosystems.
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347

348 3. Identifying long term adaptation policy directions for deltas

349 With a view to creating a set of adaptation policy directions for deltas, a three step process was
350 adopted: i) identify current policy-led adaptation actions in deltas in Ghana, India, and Bangladesh
351 (using the framing method in section 2); ii), create narratives of adaptation policy directions; and iii)
352 highlight adaptation trade-offs inherent in each policy direction.

353 3.1. Step 1: Identify current policy-led adaptation actions in deltas

354 Adaptation actions were identified using an inventory of observed adaptations, delta-wide
355 adaptation policy analyses, and a literature search on transformational adaptation. First, to generate
356 evidence of observed adaptations, we conducted a keyword search using ISI Web of Science. Each
357 delta team employed specific search terms appropriate to the type of hazard they experienced. For
358 example, Bangladesh used terms such as "Climat*", "Adapt*", "Cyclon*", "Flood*", "Salin*" coupled with the term "Bangladesh". Papers were deemed suitable for inclusion if they documented
359 observed (and not theoretical) examples of adaptation, included a study area that was within the
360 boundaries of the DECCMA deltas, had been peer-reviewed, and were published in English. To
361 identify articles from the grey literature (e.g. NGO reports) we used a snowballing method where
362 we discussed the findings of the peer-reviewed literature search with country experts who then
363 sought out relevant grey literature { ADDIN EN.CITE <EndNote><Cite><Author>Hagen-
364 Zanker</Author><Year>2013</Year><RecNum>718</RecNum><DisplayText>(Hagen-Zanker and
365 Mallett, 2013)</DisplayText><record><rec-number>718</rec-number><foreign-keys><key
366 app="EN" db-id="vx99swex92xxtwettvxxxzppt2edff2zwe0a2">718</key></foreign-keys><ref-type
367 name="Journal Article">17</ref-type><contributors><authors><author>Hagen-Zanker,
368 Jessica</author><author>Mallett, R</author></authors></contributors><titles><title>How to do a

369

370 rigorous, evidence-focused literature review in international development, A Guidance
 371 Note</title><secondary-title>London: Overseas Development Institute</secondary-
 372 title></titles><periodical><full-title>London: Overseas Development Institute</full-
 373 title></periodical><dates><year>2013</year></dates><urls></urls></record></Cite></EndNote>}.
 374 The output of these searches generated an inventory of 122 adaptations that included strategies
 375 such as post disaster mobile water treatment plants or training on new farming methods. Of these,
 376 93 documents relate to the GBM delta (85 from Bangladesh and 8 from the Indian Bengal Delta), 14
 377 refer to the Mahanadi, and 15 to the Volta.

378 Second, each DECCMA country team conducted a review of current and proposed adaptation policy
 379 in the study areas { ADDIN EN.CITE { ADDIN EN.CITE.DATA }}. Thirty-one policy documents from the
 380 GBM were included in the review (21 from Bangladesh and 10 from the Indian Bengal Delta); 21
 381 policy documents from the Mahanadi were included; and 18 from Ghana. Third, a literature search
 382 was undertaken on transformative adaptation to document the types of adaptations that could be
 383 considered radical, new and of a scale or intensity so the whole deltaic system is transformed, either
 384 socially, physically, or both { ADDIN EN.CITE

385 <EndNote><Cite><Author>Vincent</Author><Year>2017</Year><RecNum>5617</RecNum><Display
 386 Text>(Kates et al., 2012; Vincent, 2017)</DisplayText><record><rec-number>5617</rec-
 387 number><foreign-keys><key app="EN" db-id="552vavf0m5009dezrviv5909wperzvdf9at9"
 388 timestamp="1512399975">5617</key></foreign-keys><ref-type name="Report">27</ref-
 389 type><contributors><authors><author>Vincent, K. </author></authors><secondary-
 390 authors><author>DECCMA</author></secondary-authors><tertiary-authors><author>DECCMA,
 391 University of Southampton</author></tertiary-
 392 authors></contributors><titles><title>Transformational adaptation: A review of examples from 4
 393 deltas to inform the design of DECCMA's Adaptation Policy Trajectories</title><secondary-
 394 title>DECCMA Working Papers</secondary-
 395 title></titles><pages>18</pages><dates><year>2017</year></dates><pub-location>Southampton,

396 UK</pub-location><publisher>University of
 397 Southampton</publisher><urls></urls></record></Cite><Cite><Author>Kates</Author><Year>2012
 398 </Year><RecNum>31</RecNum><record><rec-number>31</rec-number><foreign-keys><key
 399 app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">31</key></foreign-keys><ref-type
 400 name="Journal Article">17</ref-type><contributors><authors><author>Kates, Robert
 401 W</author><author>Travis, William R</author><author>Wilbanks, Thomas
 402 J</author></authors></contributors><titles><title>Transformational adaptation when incremental
 403 adaptations to climate change are insufficient</title><secondary-title>Proceedings of the National
 404 Academy of Sciences</secondary-title></titles><periodical><full-title>Proceedings of the National
 405 Academy of Sciences</full-title></periodical><pages>7156-
 406 7161</pages><volume>109</volume><number>19</number><dates><year>2012</year></dates><
 407 isbn>0027-8424</isbn><urls></urls></record></Cite></EndNote>}.

408 All data were analysed consistently within the three DECCMA deltas using a data collection and
 409 analysis template, developed by { ADDIN EN.CITE <EndNote><Cite
 410 AuthorYear="1"><Author>Tompkins</Author><Year>2010</Year><RecNum>2119</RecNum><Displ
 411 ayText>Tompkins et al. (2010</DisplayText><record><rec-number>2119</rec-number><foreign-
 412 keys><key app="EN" db-id="552vavf0m5009dezrviv5909wperzvdf9at9"
 413 timestamp="1334223947">2119</key></foreign-keys><ref-type name="Journal Article">17</ref-
 414 type><contributors><authors><author>Emma L. Tompkins</author><author>Emily
 415 Boyd</author><author>Sophie Nicholson-Cole</author><author>W Neil
 416 Adger</author><author>Keith Weatherhead</author><author>Nigel W
 417 Arnell</author></authors></contributors><titles><title>Observed adaptation to climate change: UK
 418 evidence of transition to a well-adapting society?</title><secondary-title>Global Environmental
 419 Change</secondary-title></titles><periodical><full-title>Global Environmental Change</full-
 420 title></periodical><pages>627-
 421 635</pages><volume>20</volume><dates><year>2010</year></dates><urls></urls></record></Cit

e></EndNote>}} and described in { ADDIN EN.CITE <EndNote><Cite
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 yText>Tompkins et al. (2017</DisplayText><record><rec-number>605</rec-number><foreign-
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 </author><author>Suckall, N., </author><author>Vincent, K., </author><author>Rahman, R.,
 </author><author>Mensah, A., </author><author>Ghosh,
 T.,</author></authors></contributors><titles><title>Observed adaptation in deltas. DECCMA
 Working Paper, Deltas, Vulnerability and Climate Change: Migration and Adaptation, IDRC Project
 Number 107642. Available online at: www.deccma.com, Accessed 27 November
 2017</title></titles><dates><year>2017</year></dates><urls></urls></record></Cite></EndNote>}
). For each adaptation found in the literature, information categorised based on five core questions
 asked by { ADDIN EN.CITE
 <EndNote><Cite><Author>Smit</Author><Year>2001</Year><RecNum>719</RecNum><DisplayText
 >(Smit and Pilifosova, 2001)</DisplayText><record><rec-number>719</rec-number><foreign-
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 keys><ref-type name="Book Section">5</ref-type><contributors><authors><author>Smit,
 B</author><author>Pilifosova, O</author></authors><secondary-authors><author>McCarthy,
 J.J</author><author>Canziani, O</author><author>Leary, N. A</author><author>Dokken, D.
 J</author><author>White, K. S</author></secondary-authors></contributors><titles><title>Chapter
 18, Adaptation to climate change in the context of sustainable development and
 equity</title><secondary-title>Climate Change 2001: Impacts, Adaptation, Vulnerability.
 Contribution of Working Group II. Third Assessment Report of the Intergovernmental Panel on
 Climate Change</secondary-title></titles><pages>877-
 912</pages><dates><year>2001</year></dates><pub-location>Cambridge University Press,
 Cambridge</pub-location><urls></urls></record></Cite></EndNote>}: Form: what does the

adaptation look like?; Purposefulness: why is the adaptation being undertaken?; Provider /beneficiary: who is providing the adaptation and who is benefiting from it?; Timing: is the adaptation occurring in response to or in anticipation of climate change?; Function / effects: what is the broad aim of in terms of addressing drivers of vulnerability, reduce disaster risk, and/or building landscape/ecosystem resilience. As with all methods, this approach has its limitations, notably, only published works are included and as such, adaptations that have not been reported in the literature may have been missed. The list of adaptation interventions therefore may not reflect all the adaptations that are currently happening in deltas.

The adaptations identified included actions undertaken autonomously by households, non-governmental organisations (NGOs) and governments. As the focus of this method is on policy-led adaptation the household adaptations were removed, and the remaining government and NGO-led adaptations were grouped into 67 discrete types, using the high level categorisation of adaptations set out in Table 2. The next step describes the four different policy directions that policymakers may choose to follow. For each of the four policy directions, the adaptations in Table 2 are either more/less important, or do not feature at all.

Table 2: Current or planned policy-led adaptations in DECCMA deltas

Broad objective of adaptation	Adaptation actions
Addressing drivers of vulnerability	<ol style="list-style-type: none"> Promote livelihood diversification (farming) Switch livelihoods (from farming to off-farm) and develop non-farm industry Promote livelihood diversification (fishing) Promote livelihood diversification - off-farm activity Livelihood diversification – fishing Education for non-farm livelihoods, based within the delta (e.g. STEM livelihoods) Education for non-farm livelihoods, based outside the delta (e.g. STEM livelihoods) Agricultural extension to provide training on how to increase income at the household level, e.g. by providing new farming or fishing techniques. Availability of business and household loans at government level Incentives for migration to economic expansion areas Financial incentives to relocate outside of the worst affected parts of the delta

	12. Promote private sector investments in eco-tourism through economic incentives 13. Establish agriculture and fisheries based insurance schemes 14. Post-harvest production and storage at local level (e.g. farmer level) 15. Develop and use open spaces, green belts and other ecologically sensitive areas for alternative livelihoods such as urban farming 16. Use of climate resilient farming techniques 17. Farmer led cooperatives that reduce the cost of production/distribution 18. Improving access to markets for all, including infrastructure and training 19. Fishing zones/rights for small-scale fishers 20. Land reclamation and redistribution (to the poor or other groups)
Disaster Risk Reduction	21. All-Risk-changing-modifications to homes (e.g., height of foundations/walls/floors, climate resilient cluster housing) and local facilities (e.g., raise water sources and sanitation facilities above flood levels) through funding, loans and new building standards and codes 22. Raise land using controlled sedimentation 23. Beach nourishment 24. Land zoning, including no build zones 25. Education at school level re. responsibilities for DRR management e.g. evacuation training 26. Active stakeholder engagement in design and delivery of DRR 27. Communication and information re. individual roles and responsibilities re DRR 28. Readiness of emergency services to distribute medicines, food and potable water 29. Availability of DRR insurance 30. Rehabilitation and upgrading of reservoirs for water storage (e.g. dredging, raising spillway levels) 31. Funding to reduce risks to agriculture (Government-run Agriculture Disaster Mitigation Fund) 32. Multipurpose shelters including flood and cyclone shelters used in conjunction with early warning systems 33. River/coastal management defence infrastructure (including sea walls, groynes, dikes and polders) 34. Climate-proof grain silos/storage (at national and local level) 35. Ensure food availability during floods (e.g. Floating gardens and hanging vegetable garden) 36. Train community in DRR management 37. Train community in water management 38. Maintain existing infrastructure 39. Initiatives to promote economy recovery, e.g. funding to rebuild damaged economic assets such as ports, roads and grain stores 40. Temporary evacuation 41. Use of emergency responders 42. Secondment of army or national resources 43. Post disaster mobile water treatment plants 44. Post disaster house construction 45. Managed/forced relocation of households from disaster-affected areas
Landscape/ecosystem resilience	46. Climate tolerant crops 47. Changing crop varieties 48. Seed bank for crop diversification 49. Climate tolerant aquaculture (e.g. brackish shrimp) 50. Alternative climate proof grasses for cattle 51. Mixed land use (e.g. polder and freshwater shrimp farm with rice)

	52. Changing irrigation and water level management practices to improve agriculture 53. Potable water management 54. Promote saline tolerant trees to prevent erosion around farms and homes 55. Use of agro-chemicals to boost agricultural productivity and treat salinity 56. River course management 57. Mangrove forest planting 58. Agroforestry 59. Afforestation - Promote ecological restoration of degraded and poorly stocked forests 60. Tree planting in public areas 61. Create incentives for investor in tree crops and plantation (tax relief for private sector investment in research and development) 62. Reduce the pressure on forests for wood-fuels by encouraging use of renewable energy 63. No commercial mining in forested areas 64. Afforestation – climate tolerant bamboo 65. Create biological corridors between existing conservation areas to maintain gene flows 66. Promote establishment of protected green spaces with native grass along waterways 67. Conserve wildlife and biodiversity in natural heritage sites including sacred groves, protected areas
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467 3.2 Step 2: Creating narratives of the adaptation policy directions

468 In creating the directions for policy, we note two key limiting variables that influence adaptation

469 policy choice: the investment cost of the adaptation, and the extent to which significant policy

470 change, and hence political effort, is required { ADDIN EN.CITE { ADDIN EN.CITE.DATA }}. The

471 adaptations in Table 2 reflect a diversity of costs and effort required. They range from minimal to

472 high cost, and from requiring a small or incremental change to a significant change from the status

473 quo. This spectrum of cost, and willingness to commit to substantial change from the status quo

474 have been recognised in earlier research on infrastructure systems { ADDIN EN.CITE

475 <EndNote><Cite><Author>Hall</Author><Year>2016</Year><RecNum>598</RecNum><DisplayText

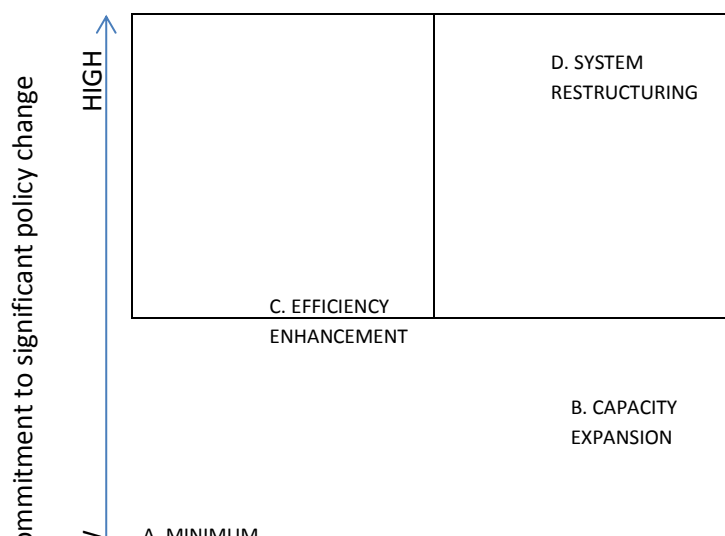
476 >(Hall et al., 2016; Hickford et al., 2015)</DisplayText><record><rec-number>598</rec-

477 number><foreign-keys><key app="EN" db-

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479 Section">5</ref-type><contributors><authors><author>Hall, Jim, </author><author>Otto,

480 Alexander, </author><author>Hickford, Adrian J, </author><author>Nicholls, Robert J,
 481 </author><author>Tran, Martino, </author></authors><secondary-authors><author>Hall, M. Tran,
 482 </author><author>A. Hickford,</author><author>R. Nicholls ,</author></secondary-
 483 authors></contributors><titles><title>A framework for analysing the long-term performance of
 484 interdependent infrastructure systems</title><secondary-title>The future of national infrastructure:
 485 A system-of-systems approach (p. 338)</secondary-
 486 title></titles><pages>12</pages><dates><year>2016</year></dates><pub-location>Cambridge:
 487 Cambridge University Press.</pub-
 488 location><isbn>1316558657</isbn><urls></urls></record></Cite><Cite><Author>Hickford</Author
 489 ><Year>2015</Year><RecNum>680</RecNum><record><rec-number>680</rec-number><foreign-
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 491 keys><ref-type name="Journal Article">17</ref-type><contributors><authors><author>Hickford,
 492 Adrian J</author><author>Nicholls, Robert J</author><author>Otto,
 493 Alexander</author><author>Hall, Jim W</author><author>Blainey, Simon P</author><author>Tran,
 494 Martino</author><author>Baruah,
 495 Pranab</author></authors></contributors><titles><title>Creating an ensemble of future strategies
 496 for national infrastructure provision</title><secondary-title>Futures</secondary-
 497 title></titles><periodical><full-title>Futures</full-title></periodical><pages>13-
 498 24</pages><volume>66</volume><dates><year>2015</year></dates><isbn>0016-
 499 3287</isbn><urls></urls></record></Cite></EndNote>} and the same approach was used here to
 500 consider what might drive governments to adopt different adaptation actions (Figure 3).



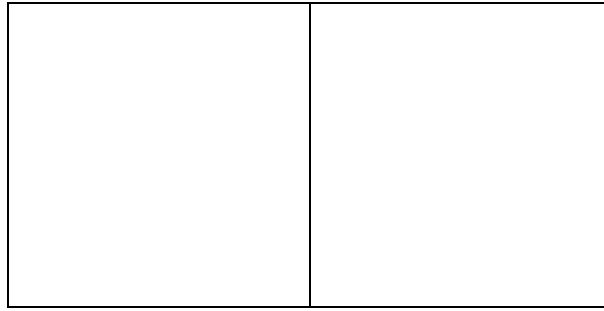


Figure 3: Drivers of government-led adaptation policy choice

Drawing on this four quadrant categorisation, a set of distinctly different cost and effort sets of plausible adaptation directions are developed for deltas.

A. *Minimum Intervention (low investment/low commitment to policy change)* is a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts. This strategy addresses those areas where maximum impact can be achieved for the lowest cost, requires low levels of commitment to policy change and promotes adaptations that require little investment. This direction reflects either a fundamental preference for a non-interventionist government, or a government lacking ambition or the capacity to act. It may also reflect the position of a government that feels that no further action is required. There is little planning for climate events, instead, the government provides a basic emergency response.

B. *Capacity Expansion (high investment/low commitment to policy change)* encourages climate-proof economic growth, but does not seek to make significant change to the current structure of the economy. A high level of investment is required to prepare the economy for future change, but adaptation policy does not aim to reorient the economy, or create significant change. Instead, the focus is on climate proofing industry and enhancing ability to adapt to changes.

C. *Efficiency Enhancement (medium investment/medium commitment to policy change)* is an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system, looking at ways of distributing labour, balancing livelihood choices, and best utilising ecosystem services to enhance livelihoods and wellbeing under climate change. As this policy direction is about efficiency, it requires less investment than other interventionist approaches (i.e. capacity enhancement and system restructuring). However, there is a reasonable commitment to significant policy change as the system moves toward supporting people to adapt to long term change.

D. *System Restructuring (high investment/high commitment to change)* embraces pre-emptive fundamental change at every level in order to completely transform the current social and ecological system, and change the social and physical functioning of the delta system. There is a guiding belief that significant/radical landscape modifications are justified to create long term system restructuring despite the short term costs that may be accrued, among some social groups, or economic sectors. Within this broad policy direction are three possible sub-directions which each seek a different end goal. The first is 'protect', broadly following the Dutch model with use of extensive protective infrastructure and significant landscape changes to protect the current status quo in terms of livelihoods { ADDIN EN.CITE

<EndNote><Cite><Author>VanKoningsveld</Author><Year>2008</Year><RecNum>675</RecNum><DisplayText>(VanKoningsveld et al., 2008)</DisplayText><record><rec-number>675</rec-number><foreign-keys><key app="EN" db-id="vx99swex92xxtwettvxxzp2edff2zwe0a2">675</key></foreign-keys><ref-type name="Journal Article">17</ref-type><contributors><authors><author>VanKoningsveld, Mark</author><author>Mulder, JPM</author><author>Stive, MJF</author><author>VanDerValk, L</author><author>VanDerWeck, AW</author></authors></contributors><titles><title>Living with sea-level rise and climate change: a case study of the Netherlands</title><secondary-title>Journal of Coastal

Research</secondary-title></titles><periodical><full-title>Journal of Coastal Research</full-
 title></periodical><pages>367-379</pages><dates><year>2008</year></dates><isbn>1551-
 5036</isbn><urls></urls></record></Cite></EndNote>}. Under this policy, land is protected
 from any further change so that communities can continue to maintain traditional livelihoods
 such as farming or fishing. The second is '*accommodate*', as is evolving in the Mississippi delta
 where livelihoods have significantly changed in order to 'live with nature' and there is an
 aspiration to 'work with nature' to adapt to changes to the natural environment { ADDIN EN.CITE
 <EndNote><Cite><Author>Day</Author><Year>2014</Year><RecNum>683</RecNum><Display
 Text>(Day et al., 2014)</DisplayText><record><rec-number>683</rec-number><foreign-
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 W</author><author>Kemp, G Paul</author><author>Freeman, Angelina
 M</author><author>Muth, David
 P</author></authors></contributors><titles><title>Introduction: Perspectives on the
 restoration of the Mississippi Delta</title><secondary-title>Perspectives on the Restoration of
 the Mississippi Delta</secondary-title></titles><pages>1-
 7</pages><dates><year>2014</year></dates><publisher>Springer</publisher><urls></urls></r
 ecord></Cite></EndNote>}. The third is '*retreat*' or abandonment of the delta in terms of
 population, for example, through a policy of population and infrastructural relocation { ADDIN
 EN.CITE
 <EndNote><Cite><Author>Dun</Author><Year>2011</Year><RecNum>684</RecNum><Display
 Text>(Dun, 2011)</DisplayText><record><rec-number>684</rec-number><foreign-keys><key
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ates><isbn>1468-2435</isbn><urls></urls></record></Cite></EndNote>}. All three
restructuring policies require a high level of investment and a high commitment to significant
policy change.

3.3 Step 3: Exploring adaptation trade-offs

Having developed a conceptualisation of adaptation, collated evidence of adaptation, and designed
a contrasting set of adaptation policy directions, the next step is to allocate specific adaptation
measures to each direction. To do this, a more nuanced understanding of each policy direction is
required where each of the 13 adaptation classes are given relative weights to reflect the relative
levels of investment, and political willingness to change. In the context of finite resources, this
approach also identifies the trade-offs that occur between the 13 adaptation classes. Due to the
complexity of the task, and following { ADDIN EN.CITE <EndNote><Cite
AuthorYear="1"><Author>Brooks</Author><Year>2005</Year><RecNum>1243</RecNum><DisplayT
ext>Brooks et al. (2005</DisplayText><record><rec-number>1243</rec-number><foreign-keys><key
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type><contributors><authors><author>Nick Brooks</author><author>W. Neil
Adger</author><author>P. M. Kelly</author></authors></contributors><titles><title>The
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163</pages><volume>15</volume><number>2</number><dates><year>2005</year><pub-
dates><date>July 2005</date></pub-dates></dates><urls></urls></record></Cite></EndNote>}},
an expert interdisciplinary group of eight delta research scientists (in the fields of climate change

adaptation, engineering, systems modelling, population and development, and geography) were asked to deliberate on the relative investment availability under each policy direction, and to assign weights to reflect this investment (Table 3). Low, medium and high levels of investment were represented by three weights allocated out of 40. Hence direction A (the least costly) is weighted 20; B is weighted 40; C is weighted 30; and, D is weighted 40. These weights constrain the quantities and focus of adaptation under each direction, thus highlighting the investment directions under each scenario. This however, also means that some adaptation measures may be ignored altogether.

Table 3: Weights assigned to policy directions

Broad objective of adaptation	Class of adaptation	Policy direction					
		A. Minimum intervention	B. Capacity expansion	C. System efficiency	D. System restructuring		
					Protect	Accommodate	Retreat
Addressing drivers of vulnerability	1. Financial capital	0	8	0	3	15	10
	2. Human capital	5	7	6	3	15	10
	3. Social capital	0	0	6	0	0	0
	4. Natural capital	0	0	4	3	0	0
	5. Physical capital	0	5	0	0	0	0
DRR	6. Managing long term risk	1	4	4	20	10	0
	7. Preparedness	0	2	3	0	0	0
	8. Response	4	2	0	0	0	0
	9. Post disaster recovery and rehabilitation	4	2	0	0	0	20
Landscape/ ecosystem resilience	10. Provisioning	6	5	3	10	0	0
	11. Regulating	0	5	1	1	0	0
	12. Habitat	0	0	1	0	0	0
	13. Cultural	0	0	2	0	0	0
	Total investment	20	40	30	40	40	40

The expert group also determined how ‘significant policy change’ could be represented by allocating the points within each policy direction across the 13 adaptation classes. The points within each adaptation class were allocated using a two stage subjective weighting process. First, for each

policy direction, each expert was asked to rank the 13 classes in order of importance. Then, in a collaborative workshop, the experts deliberated on the order of the classes for each policy direction until consensus was achieved. Second, the experts were asked to assign the points available under each policy direction to each of the classes based on their importance. Again, this was done through an open process of deliberation until consensus was achieved. As with any subjective decision making process, the outcome is informed by the knowledge, perceptions and experience of the decision makers. Thus a potential limitation arises.

Using this approach, the least costly policy direction, Minimum Intervention spreads limited resources across six of the 13 classes of adaptation. However, one of the three most ambitious directions, System Restructuring (Retreat) divides more substantial resources across just three classes of adaptation and uses half of its significant resources on post disaster recovery and rehabilitation alone. Using this weighting system it is possible to constrain the relative scope and types of adaptation present in each policy direction to understand where trade-offs occur.

4. Understanding adaptation policy choices in deltas

Using the methods described in section three, this section explores more deeply the nature and structure of the adaptation policy directions. The policy directions offer a vision of some of the feasible adaptation futures within deltas, taking into account the main objectives of adaptation, and the adaptation actions that currently occur in deltas. The impacts of each direction can only be understood through an analysis of the specific adaptation choices that it promotes. To populate the four policy directions, the 67 adaptation types in Table 2 were categorised using the 13 classes of adaptation (see Tables 4-7). Each adaptation can appear in more than one of the policy directions. For example, the adaptation intervention to ‘promote private sector investments in eco-tourism through economic incentives’, was categorised under “1. *Financial capital – addressing drivers of*

vulnerability". It was then assigned to the Capacity Expansion policy direction as it offers a non-farm income generating activity, which sits alongside traditional farm based livelihoods. It was also assigned to the System Restructuring (Accommodate) policy direction as it may enable a complete shift from farm-based to non-farm-based livelihood activities that are more suited to a changed environment. For each of the four policy directions, we detail the adaptation options that might occur within them, highlighting areas that are less important, or that are ignored all together.

4.1. *The Minimum Intervention adaptation choices*

Vulnerability is reduced through investing in human capital. There is little or no investment in other forms of capital. Investment in *human capital* may include basic training on how to increase income at the household level, such as learning new farming or fishing techniques. For example, India's Central Rice Research Institute (CRRI) provide support and training to farmers to develop integrated rice-fish farming systems on flood prone land in Odisha { ADDIN EN.CITE <EndNote><Cite ExcludeAuth="1"><Author>Regional Centre for Development Cooperation (RCDC)</Author><Year>2011</Year><RecNum>642</RecNum><Prefix>RCDC`, </Prefix><DisplayText>(RCDC, 2011)</DisplayText><record><rec-number>642</rec-number><foreign-keys><key app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">642</key></foreign-keys><ref-type name="Serial">57</ref-type><contributors><authors><author>Regional Centre for Development Cooperation (RCDC),</author></authors></contributors><titles><title>Integrated Rice Fish Culture Climate Change Adaptation Option Paribartan Project in Kendrapara and Jagatsinghpur</title></titles><dates><year>2011</year></dates><publisher>Available online at <https://www.rcdcindia.org/PbDocument/995fd0d595e6ccf-173e-455b-a9f9-796e461137e6IRFC%20as%20CC%20Adaptation%20Option.pdf>. Accessed 18 December 2017</publisher><urls></urls></record></Cite></EndNote>} The CRRI also provide training so

662 farmers can grow new varieties of fruit, vegetables and trees. Other similar schemes were reported
663 { ADDIN EN.CITE { ADDIN EN.CITE.DATA }}.

664 DRR is delivered in three ways. First, through simple measures to *address long term risk*, such as
665 training farmers to create floating gardens on flooded land { ADDIN EN.CITE

666 <EndNote><Cite><Author>Action</Author><Year>2011</Year><RecNum>647</RecNum><DisplayText>(Practical Action, 2011)</DisplayText><record><rec-number>647</rec-number><foreign-keys><key app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">647</key></foreign-keys><ref-type name="Report">27</ref-type><contributors><authors><author>Practical
667 Action,</author></authors></contributors><titles><title>Floating gardens in
671 Bangladesh</title></titles><dates><year>2011</year></dates><pub-location>Available online at:
672 <http://www.fao.org/climatechange/17849-0e277b46b31f98942e6bc81bb22319243.pdf>. Last
673 accessed 18 December 2017</pub-location><urls></urls></record></Cite></EndNote>}. Second,
674 through *disaster response* such as temporary evacuation, emergency responders and the
675 secondment of the army or national resources. For example, WWF-India has helped train disaster
676 management teams in West Bengal who receive state support to help the community during
677 extreme events { ADDIN EN.CITE

678 <EndNote><Cite><Author>Danda</Author><Year>2010</Year><RecNum>648</RecNum><DisplayText>(Danda, 2010)</DisplayText><record><rec-number>648</rec-number><foreign-keys><key
679 app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">648</key></foreign-keys><ref-type
680 name="Journal Article">17</ref-type><contributors><authors><author>Danda,
682 A</author></authors></contributors><titles><title>Sundarbans: Future Imperfect–Climate
683 Adaptation Report. New Delhi: World Wide Fund for Nature–India. Available at http://assets.wwfindia.org/downloads/sundarbans_future_imperfect__climate_adaptation_report.pdf.
684 [tp</title><secondary-title>assets. wwfindia.
685 org/downloads/sundarbans_future_imperfect__climate_adaptation_report.pdf</secondary-
686 title></titles><periodical><full-title>assets. wwfindia.
687 org/downloads/sundarbans_future_imperfect__climate_adaptation_report.pdf</full-](http://assets.wwfindia.org/downloads/sundarbans_future_imperfect__climate_adaptation_report.pdf)

688 title></periodical><dates><year>2010</year></dates><urls></urls></record></Cite></EndNote>}.
689 Third, basic services are provided during post *disaster recovery and rehabilitation*, such as post
690 disaster mobile water treatment plants and post disaster house construction for the worst affected
691 households. For example, following Cyclone Komen (2015) the Bangladesh Red Crescent Society
692 (BDRCS) distributed cash grants, 3,000 tarpaulins, 30,000 packets of oral rehydration solution and
693 installed two mobile water treatment plants in the worst affected areas { ADDIN EN.CITE
694 <EndNote><Cite ExcludeAuth="1"><Author>International Federation of Red Cross and Red Cresent
695 Societies (IFRC)</Author><Year>2015</Year><RecNum>649</RecNum><Prefix>IFRC`,
696 </Prefix><DisplayText>(IFRC, 2015)</DisplayText><record><rec-number>649</rec-
697 number><foreign-keys><key app="EN" db-
698 id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">649</key></foreign-keys><ref-type
699 name="Report">27</ref-type><contributors><authors><author>International Federation of Red
700 Cross and Red Cresent Societies (IFRC),</author></authors></contributors><titles><title>Emergency
701 appeal operations update Bangladesh: Cyclone
702 Komen</title></titles><dates><year>2015</year></dates><pub-location>Available online at
703 https://reliefweb.int/sites/reliefweb.int/files/resources/MDRBD015_OU2%20%281%29.pdf. Last
704 accessed 19 December 2017</pub-location><urls></urls></record></Cite></EndNote>}.
705 *Ecosystem resilience* is delivered through some basic *provisioning services*, which are partially
706 supported through training services such as potable water management. For example, in Bangladesh,
707 UNICEF and the Department of Public Health have introduced pond sand filters (PSFs) along the
708 coastal belt { ADDIN EN.CITE
709 <EndNote><Cite><Author>Ahmed</Author><Year>2010</Year><RecNum>651</RecNum><DisplayT
710 ext>(Ahmed, 2010)</DisplayText><record><rec-number>651</rec-number><foreign-keys><key
711 app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">651</key></foreign-keys><ref-type
712 name="Report">27</ref-type><contributors><authors><author>Ahmed,
713 AU</author></authors></contributors><titles><title>Reducing vulnerability to climate change: the

714 pioneering example of community based adaptation in
 715 Bangladesh</title></titles><pages>156</pages><dates><year>2010</year></dates><pub-
 716 location>Centre for Global Change (CGC) and CARE Bangladesh, Dhaka</pub-
 717 location><isbn>9843322347</isbn><urls></urls></record></Cite></EndNote>}. There is no support
 718 for other ecosystem services. See Table 4, for details of the specific adaptation interventions.

719 4.2 The Capacity Expansion adaptation choices

720 *Vulnerability* reduction is the main focus of this policy direction with the prime focus is on improving
 721 *financial capital*. This is done at the household level, for example training on post-harvest production
 722 and storage { ADDIN EN.CITE

723 <EndNote><Cite><Author>Chowdhury</Author><Year>2011</Year><RecNum>655</RecNum><Disp
 724 layText>(Chowdhury et al., 2011)</DisplayText><record><rec-number>655</rec-number><foreign-
 725 keys><key app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">655</key></foreign-
 726 keys><ref-type name="Journal Article">17</ref-type><contributors><authors><author>Chowdhury,
 727 Ataharul Huq</author><author>Van Mele, Paul</author><author>Hauser,
 728 Michael</author></authors></contributors><titles><title>Contribution of Farmer-to-Farmer Video
 729 to Capital Assets Building: Evidence from Bangladesh</title><secondary-title>Journal of Sustainable
 730 Agriculture</secondary-title></titles><periodical><full-title>Journal of Sustainable Agriculture</full-
 731 title></periodical><pages>408-

732 435</pages><volume>35</volume><number>4</number><dates><year>2011</year><pub-
 733 dates><date>2011/04/04</date></pub-dates></dates><publisher>Taylor & amp;

734 Francis</publisher><isbn>1044-0046</isbn><urls><related-

735 urls><url>https://doi.org/10.1080/10440046.2011.562059</url></related-urls></urls><electronic-
 736 resource-num>10.1080/10440046.2011.562059</electronic-resource-

737 num></record></Cite></EndNote>} and government and NGO provided loans { ADDIN EN.CITE

738 <EndNote><Cite><Author>Aveh</Author><Year>2013</Year><RecNum>653</RecNum><DisplayTex
 739 t>(Aveh et al., 2013; Nukpezah and Blankson, 2017)</DisplayText><record><rec-number>653</rec-

number><foreign-keys><key app="EN" db-
 id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">653</key></foreign-keys><ref-type name="Journal
 Article">17</ref-type><contributors><authors><author>Aveh, FK</author><author>Dadzie,
 PS</author><author>Krah, RY</author></authors></contributors><titles><title>Success of
 microfinance institutions: the Ghanaian experience</title><secondary-title>International Business
 and Management</secondary-title></titles><periodical><full-title>International Business and
 Management</full-title></periodical><pages>91-
 97</pages><volume>6</volume><number>2</number><dates><year>2013</year></dates><isbn>1
 923-
 8428</isbn><urls></urls></record></Cite><Cite><Author>Nukpezah</Author><Year>2017</Year><
 RecNum>654</RecNum><record><rec-number>654</rec-number><foreign-keys><key app="EN"
 db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">654</key></foreign-keys><ref-type
 name="Journal Article">17</ref-type><contributors><authors><author>Nukpezah, Julius
 A.</author><author>Blankson,
 Charles</author></authors></contributors><titles><title>Microfinance Intervention in Poverty
 Reduction: A Study of Women Farmer-Entrepreneurs in Rural Ghana</title><secondary-title>Journal
 of African Business</secondary-title></titles><periodical><full-title>Journal of African
 Business</full-title></periodical><pages>457-
 475</pages><volume>18</volume><number>4</number><dates><year>2017</year><pub-
 dates><date>2017/10/02</date></pub-
 dates></dates><publisher>Routledge</publisher><isbn>1522-8916</isbn><urls><related-
 urls><url>https://doi.org/10.1080/15228916.2017.1336915</url></related-urls></urls><electronic-
 resource-num>10.1080/15228916.2017.1336915</electronic-resource-
 num></record></Cite></EndNote>}. For example, micro-credit based by the World Health
 Organization (WHO) in the Volta have shown a reduction in poverty among women farmer-
 entrepreneurs. Vulnerability reduction is also done at the government level, for example, by

766 encouraging private sector investment in ecotourism, which is a policy goal in Ghana { ADDIN
767 EN.CITE <EndNote><Cite><Author>Government of the Republic of
768 Ghana</Author><Year>2013</Year><RecNum>656</RecNum><DisplayText>(Government of the
769 Republic of Ghana, 2013)</DisplayText><record><rec-number>656</rec-number><foreign-
770 keys><key app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">656</key></foreign-
771 keys><ref-type name="Report">27</ref-type><contributors><authors><author>Government of the
772 Republic of Ghana,</author></authors></contributors><titles><title>National Tourism
773 Development Plan (2013 – 2027)</title></titles><dates><year>2013</year></dates><pub-
774 location>Available online at: [http://www.ghana.travel/wp-content/uploads/2016/11/Ghana-](http://www.ghana.travel/wp-content/uploads/2016/11/Ghana-Tourism-Development-Plan.pdf)
775 Tourism-Development-Plan.pdf. Last accessed 19 December 2017</pub-
776 location><urls></urls></record></Cite></EndNote>}. There is also an emphasis on *human capital* as
777 the government invests in training that in turn will ensure households are able to better participate
778 in the non-farm economy { ADDIN EN.CITE
779 <EndNote><Cite><Author>Haggblade</Author><Year>2010</Year><RecNum>658</RecNum><Displ
780 ayText>(Haggblade et al., 2010)</DisplayText><record><rec-number>658</rec-number><foreign-
781 keys><key app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">658</key></foreign-
782 keys><ref-type name="Journal Article">17</ref-type><contributors><authors><author>Haggblade,
783 Steven</author><author>Hazell, Peter</author><author>Reardon,
784 Thomas</author></authors></contributors><titles><title>The rural non-farm economy: Prospects
785 for growth and poverty reduction</title><secondary-title>World Development</secondary-
786 title></titles><periodical><full-title>World Development</full-title></periodical><pages>1429-
787 1441</pages><volume>38</volume><number>10</number><dates><year>2010</year></dates><is
788 bn>0305-750X</isbn><urls></urls></record></Cite></EndNote>} and on *physical capital* by
789 ensuring that appropriate infrastructure exists to support economic growth e.g. roads, storage, rural
790 electricity { ADDIN EN.CITE
791 <EndNote><Cite><Author>Deichmann</Author><Year>2009</Year><RecNum>657</RecNum><Disp

layText>(Deichmann et al., 2009; Sharma, 2007)</DisplayText><record><rec-number>657</rec-
number><foreign-keys><key app="EN" db-
id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">657</key></foreign-keys><ref-type name="Journal
Article">17</ref-type><contributors><authors><author>Deichmann, Uwe</author><author>Shilpi,
Forhad</author><author>Vakis, Renos</author></authors></contributors><titles><title>Urban
proximity, agricultural potential and rural non-farm employment: Evidence from
Bangladesh</title><secondary-title>World Development</secondary-title></titles><periodical><full-
title>World Development</full-title></periodical><pages>645-
660</pages><volume>37</volume><number>3</number><dates><year>2009</year></dates><isbn
>0305-
750X</isbn><urls></urls></record></Cite><Cite><Author>Sharma</Author><Year>2007</Year><Re
cNum>659</RecNum><record><rec-number>659</rec-number><foreign-keys><key app="EN" db-
id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">659</key></foreign-keys><ref-type name="Journal
Article">17</ref-type><contributors><authors><author>Sharma, Dinesh
C</author></authors></contributors><titles><title>Transforming rural lives through decentralized
green power</title><secondary-title>Futures</secondary-title></titles><periodical><full-
title>Futures</full-title></periodical><pages>583-
596</pages><volume>39</volume><number>5</number><dates><year>2007</year></dates><isbn
>0016-3287</isbn><urls></urls></record></Cite></EndNote>}.

DRR focuses on *long term risk mitigation* through hard and soft measures. For hard DRR there might
be a focus on the provision of river/coastal infrastructure to protect economically important areas,
for example, the World Bank recently invested USD 400 million to improve polder embankments in
economically important areas of Bangladesh { ADDIN EN.CITE <EndNote><Cite><Author>World
Bank</Author><Year>2013</Year><RecNum>660</RecNum><DisplayText>(World Bank,
2013)</DisplayText><record><rec-number>660</rec-number><foreign-keys><key app="EN" db-
id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">660</key></foreign-keys><ref-type

818 name="Report">27</ref-type><contributors><authors><author>World
819 Bank,</author></authors></contributors><titles><title>Coastal Embankment Improvement Project -
820 Phase I (CEIP-I)</title></titles><dates><year>2013</year></dates><pub-location>Available online at:
821 [http://projects.worldbank.org/P128276/coastal-embankment-improvement-project-phase-1ceip-](http://projects.worldbank.org/P128276/coastal-embankment-improvement-project-phase-1ceip-1?lang=en&tab=overview)
822 [1?lang=en&tab=overview](http://projects.worldbank.org/P128276/coastal-embankment-improvement-project-phase-1ceip-1?lang=en&tab=overview). Last accssed 19 December 2017</pub-
823 location><urls></urls></record></Cite></EndNote>}. For soft DRR, preparedness and risk mitigation,
824 for example through agriculture and fisheries based insurance schemes { ADDIN EN.CITE
825 <EndNote><Cite><Author>Government of the People's Republic of
826 Bangladesh</Author><Year>2009</Year><RecNum>652</RecNum><DisplayText>(Government of
827 the People's Republic of Bangladesh, 2009)</DisplayText><record><rec-number>652</rec-
828 number><foreign-keys><key app="EN" db-
829 id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">652</key></foreign-keys><ref-type
830 name="Report">27</ref-type><contributors><authors><author>Government of the People's
831 Republic of Bangladesh,</author></authors></contributors><titles><title>Crop insurance as a risk
832 management strategy in Bangladesh</title><secondary-title>Department of Environment. Ministry
833 of Environment and Forests. Government of the People's Republic of Bangladesh,
834 Dhaka</secondary-title></titles><periodical><full-title>Department of Environment. Ministry of
835 Environment and Forests. Government of the People's Republic of Bangladesh, Dhaka</full-
836 title></periodical><dates><year>2009</year></dates><urls></urls></record></Cite></EndNote>};
837 *Post-disaster recovery* efforts focus on getting the economy functioning quickly after disasters and
838 reducing the impact of natural hazards on economic sectors. For example, rapidly releasing funds to
839 rebuild damaged economic resources such as ports, roads and key grain stores.

840 *Ecosystem resilience* is delivered through investment in *provisioning services*. This is to enable
841 income from food and water production under future climate change, for example, by using saline
842 tolerant crops that can withstand coastal flooding { ADDIN EN.CITE
843 <EndNote><Cite><Author>Islam</Author><Year>2016</Year><RecNum>661</RecNum><DisplayTex

t>(Islam et al., 2016)</DisplayText><record><rec-number>661</rec-number><foreign-keys><key
app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">661</key></foreign-keys><ref-type
name="Journal Article">17</ref-type><contributors><authors><author>Islam, M.
R.</author><author>Sarker, M. R. A.</author><author>Sharma, N.</author><author>Rahman, M.
A.</author><author>Collard, B. C. Y.</author><author>Gregorio, G. B.</author><author>Ismail, A.
M.</author></authors></contributors><titles><title>Assessment of adaptability of recently released
salt tolerant rice varieties in coastal regions of South Bangladesh</title><secondary-title>Field Crops
Research</secondary-title></titles><periodical><full-title>Field Crops Research</full-
title></periodical><pages>34-43</pages><volume>190</volume><number>Supplement
C</number><keywords><keyword>Adaptability</keyword><keyword>Farmers'
preferences</keyword><keyword>Genotype×environment
analysis</keyword><keyword>Salinity</keyword><keyword>Stagnant
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urls><url>http://www.sciencedirect.com/science/article/pii/S0378429015300563</url></related-
urls></urls><electronic-resource-num>https://doi.org/10.1016/j.fcr.2015.09.012</electronic-
resource-num></record></Cite></EndNote>}. There is also a focus on *regulating services*, for
example, the use of agro-chemicals or creation of private sector incentives for tree planting. See
Table 5, for more details of the specific adaptation interventions.

863

864 4.3 The Efficiency Enhancement adaptation choices

865 *Vulnerability* is reduced by focusing on human and social capital at the household and community
866 level. In terms of *human capital*, livelihood diversification in farming is promoted as is the teaching
867 of climate resilient farming and post-harvest production methods { ADDIN EN.CITE
868 <EndNote><Cite><Author>White</Author><Year>2016</Year><RecNum>663</RecNum><DisplayTe

869 xt>(White et al., 2016)</DisplayText><record><rec-number>663</rec-number><foreign-keys><key
 870 app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">663</key></foreign-keys><ref-type
 871 name="Journal Article">17</ref-type><contributors><authors><author>White,
 872 Douglas</author><author>Quinney, Marie</author><author>Jarvis,
 873 Andy</author></authors></contributors><titles><title>Climate-Smart Agriculture (CSA) within the
 874 Feed the Future Project Portfolio of USAID-Bangladesh: A CCAFS Deep-Dive
 875 Review</title></titles><dates><year>2016</year></dates><urls></urls></record></Cite></EndNote
 876 >}. In terms of *social capital*, local farming and fishing cooperatives ensure maximum production
 877 benefits. Finally, by improving access to *natural capital*, for example through fishing permits,
 878 households are able to make the most efficient use of income generating resources { ADDIN EN.CITE
 879 <EndNote><Cite><Author>Monirul
 880 Islam</Author><Year>2014</Year><RecNum>662</RecNum><DisplayText>(Monirul Islam et al.,
 881 2014)</DisplayText><record><rec-number>662</rec-number><foreign-keys><key app="EN" db-
 882 id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">662</key></foreign-keys><ref-type name="Journal
 883 Article">17</ref-type><contributors><authors><author>Monirul Islam, Md</author><author>Sallu,
 884 Susannah</author><author>Hubacek, Klaus</author><author>Paavola,
 885 Jouni</author></authors></contributors><titles><title>Limits and barriers to adaptation to climate
 886 variability and change in Bangladeshi coastal fishing communities</title><secondary-title>Marine
 887 Policy</secondary-title></titles><periodical><full-title>Marine Policy</full-
 888 title></periodical><pages>208-216</pages><volume>43</volume><number>Supplement
 889 C</number><keywords><keyword>Climate
 890 change</keyword><keyword>Adaptation</keyword><keyword>Fishing
 891 community</keyword><keyword>Barrier</keyword><keyword>Limit</keyword><keyword>Banglad
 892 esh</keyword></keywords><dates><year>2014</year><pub-
 893 dates><date>2014/01/01</date></pub-dates></dates><isbn>0308-597X</isbn><urls><related-
 894 urls><url>http://www.sciencedirect.com/science/article/pii/S0308597X13001334</url></related-

895 urls></urls><electronic-resource-num>https://doi.org/10.1016/j.marpol.2013.06.007</electronic-
896 resource-num></record></Cite></EndNote>}.
897 DRR is provided through investments in long term risk management using relatively low cost
898 interventions such as early warning systems and cyclone shelters { ADDIN EN.CITE
899 <EndNote><Cite><Author>Danda</Author><Year>2010</Year><RecNum>648</RecNum><DisplayTe
900 xt>(Danda, 2010; Roy et al., 2015)</DisplayText><record><rec-number>648</rec-number><foreign-
901 keys><key app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">648</key></foreign-
902 keys><ref-type name="Journal Article">17</ref-type><contributors><authors><author>Danda,
903 A</author></authors></contributors><titles><title>Sundarbans: Future Imperfect–Climate
904 Adaptation Report. New Delhi: World Wide Fund for Nature–India. Available at ht
905 tp</title><secondary-title>assets. wwfindia.
906 org/downloads/sundarbans_future_imperfect__climate_adaptation_report. pdf</secondary-
907 title></titles><periodical><full-title>assets. wwfindia.
908 org/downloads/sundarbans_future_imperfect__climate_adaptation_report. pdf</full-
909 title></periodical><dates><year>2010</year></dates><urls></urls></record></Cite><Cite><Author
910 >Roy</Author><Year>2015</Year><RecNum>664</RecNum><record><rec-number>664</rec-
911 number><foreign-keys><key app="EN" db-
912 id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">664</key></foreign-keys><ref-type name="Journal
913 Article">17</ref-type><contributors><authors><author>Roy, Chandan</author><author>Sarkar,
914 Saroje Kumar</author><author>Åberg, Johan</author><author>Kovordanyi,
915 Rita</author></authors></contributors><titles><title>The current cyclone early warning system in
916 Bangladesh: providers' and receivers' views</title><secondary-title>International
917 journal of disaster risk reduction</secondary-title></titles><periodical><full-title>International
918 journal of disaster risk reduction</full-title></periodical><pages>285-
919 299</pages><volume>12</volume><dates><year>2015</year></dates><isbn>2212-
920 4209</isbn><urls></urls></record></Cite></EndNote>} , development of building codes for

921 buildings in at risk areas and no build zones and government funds to reduce risks to agriculture,
 922 such as government run Agriculture Disaster Mitigation Funds. There is also a focus on *preparedness*.
 923 Communities are trained to prepare for events through relatively low cost initiative, such as DRR
 924 education at school evacuation training and stakeholder engagement in DRR plans { ADDIN EN.CITE
 925 <EndNote><Cite><Author>Sunderban Social Development
 926 Centre</Author><Year>2012</Year><RecNum>665</RecNum><DisplayText>(Sunderban Social
 927 Development Centre, 2012; WWF-India, 2010)</DisplayText><record><rec-number>665</rec-
 928 number><foreign-keys><key app="EN" db-
 929 id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">665</key></foreign-keys><ref-type
 930 name="Report">27</ref-type><contributors><authors><author>Sunderban Social Development
 931 Centre,</author></authors></contributors><titles><title>Process Document on LEGO Risk Mapping
 932 Pilot Project (LEGO-DRR & CCA)</title><secondary-title>Available online at:
 933 <http://www.ssdcindia.org.in/gallery/1374828232Process%20Documentation%20of%20%20LEGO->
 934 [DRR%20& %20CCA.pdf](http://www.ssdcindia.org.in/gallery/1374828232Process%20Documentation%20of%20%20LEGO-) Last accessed 19 December 2017</secondary-
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 944 title></titles><dates><year>2010</year></dates><urls></urls></record></Cite></EndNote>}. There
 945 is little emphasis on *response* or *recovery*.

946 *Ecosystem resilience* is a priority as it supports efficient management and exploitation of the delta
 947 system. All four ecosystem services are recognised as contributing to wider system efficiency and all
 948 are the focus of government interventions. The focus is on low cost interventions. In terms of
 949 *provisioning*, mixed land use and irrigation are promoted { ADDIN EN.CITE
 950 <EndNote><Cite><Author>UNDP
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 958 [20Model_Forest%20Fruit%20Fish.pdf?download](http://www.bd.undp.org/content/dam/bangladesh/docs/Publications/A%20New%20Land%20Use%20Model_Forest%20Fruit%20Fish.pdf?download). Last accssed 19 December 2017</secondary-
 959 title></titles><dates><year>2011</year></dates><urls></urls></record></Cite></EndNote>}. In
 960 terms of *regulating*, tree planting, including mangroves, is the main focus { ADDIN EN.CITE { ADDIN
 961 EN.CITE.DATA }}. In terms of *habitat*, biological corridors are created, as are green spaces with native
 962 grass along waterways. Finally, in terms of *cultural* services the conservation of wildlife and
 963 biodiversity including sacred groves is promoted. See Table 6, for more details of the specific
 964 adaptation interventions.

965

966 4.4. The System Restructuring adaptation choices

967 4.4.1 System restructuring – Protect

968 This policy direction aims to significantly change the natural system to make sure that traditional,
 969 agricultural based livelihoods are protected from climate impacts. *Vulnerability* is reduced by
 970 focusing on financial, human and natural capital. In terms of *financial capital* the green belt is used

971 for farming so productivity can be maximised. In terms of *human capital*, climate resilient farming
 972 techniques are promoted, and in terms of *natural capital*, land is redistributed to poorer farmers {
 973 ADDIN EN.CITE
 974 <EndNote><Cite><Author>Devine</Author><Year>2002</Year><RecNum>673</RecNum><DisplayT
 975 ext>(Devine, 2002)</DisplayText><record><rec-number>673</rec-number><foreign-keys><key
 976 app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">673</key></foreign-keys><ref-type
 977 name="Journal Article">17</ref-type><contributors><authors><author>Devine,
 978 Joseph</author></authors></contributors><titles><title>Ethnography of a policy process: A case
 979 study of land redistribution in Bangladesh</title><secondary-title>Public Administration and
 980 Development</secondary-title></titles><periodical><full-title>Public Administration and
 981 Development</full-title></periodical><pages>403-
 982 414</pages><volume>22</volume><number>5</number><dates><year>2002</year></dates><isbn
 983 >1099-162X</isbn><urls></urls></record></Cite></EndNote>} and small-scale fishers receive fishing
 984 rights. *DRR* is the main focus with all emphasis on managing *long term risk* through, for example,
 985 raising of land elevation using controlled sedimentation { ADDIN EN.CITE
 986 <EndNote><Cite><Author>Schiermeier</Author><Year>2014</Year><RecNum>674</RecNum><Dis
 987 playText>(Schiermeier, 2014)</DisplayText><record><rec-number>674</rec-number><foreign-
 988 keys><key app="EN" db-id="vx99swex92xxtwettvxxzppt2edff2zwe0a2">674</key></foreign-
 989 keys><ref-type name="Journal Article">17</ref-type><contributors><authors><author>Schiermeier,
 990 Quirin</author></authors></contributors><titles><title>Holding back the tide</title><secondary-
 991 title>Nature</secondary-title></titles><periodical><full-title>Nature</full-
 992 title></periodical><pages>164</pages><volume>508</volume><number>7495</number><dates><
 993 year>2014</year></dates><isbn>0028-0836</isbn><urls></urls></record></Cite></EndNote>}, the
 994 creation of dikes to manage flood water, no build zones, land zoning and massive investment in
 995 river/coastal defence infrastructure. Specifically, there is significant investment in river/coastal
 996 defence infrastructure to protect the built environment including industry. This would attempt to

997 replicate the success of the Delta Project in the Netherlands { ADDIN EN.CITE

998 <EndNote><Cite><Author>VanKoningsveld</Author><Year>2008</Year><RecNum>675</RecNum><

999 DisplayText>(VanKoningsveld et al., 2008)</DisplayText><record><rec-number>675</rec-

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1004 L</author><author>VanDerWeck, AW</author></authors></contributors><titles><title>Living with

1005 sea-level rise and climate change: a case study of the Netherlands</title><secondary-title>Journal of

1006 Coastal Research</secondary-title></titles><periodical><full-title>Journal of Coastal Research</full-

1007 title></periodical><pages>367-379</pages><dates><year>2008</year></dates><isbn>1551-

1008 5036</isbn><urls></urls></record></Cite></EndNote>} *Ecosystem resilience* is a priority as the aim

1009 of this policy direction is to allow traditionally based agricultural livelihoods to continue. In terms of

1010 *provisioning*, significant land use changes and use of climate tolerant crops allow farming to

1011 continue. In terms of *regulating*, river course management and strict rules around forest use also

1012 allow farming to continue. See Table 7, for more details of the specific adaptation interventions in

1013 the three sub directions.

1014 4.4.2 System restructuring – Accommodate

1015 This policy direction aims to significantly change livelihoods (i.e. move away from traditional

1016 agricultural activities) to ensure the population can remain in the delta despite environmental

1017 change and sudden environmental shocks. *Vulnerability* is reduced by significantly focusing on

1018 financial and human capital. In terms of *financial capital*, there is an effort to promote non-farm

1019 industry within the delta, such as private sector investments in eco-tourism through economic

1020 incentives. *DRR* focuses on *managing long term risk*. There is also a focus on infrastructure that

1021 allows people to remain in potentially dangerous locations, such as early warning systems and

1022 cyclone/flood shelters { ADDIN EN.CITE

1023 <EndNote><Cite><Author>Paul</Author><Year>2009</Year><RecNum>676</RecNum><DisplayText

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1033 030X</isbn><urls></urls></record></Cite><Cite><Author>Lumbroso</Author><Year>2017</Year><

1034 RecNum>632</RecNum><record><rec-number>632</rec-number><foreign-keys><key app="EN"

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1043 >2017</year></dates><isbn>1561-8633</isbn><urls></urls></record></Cite></EndNote>}.
1044 *Ecosystem resilience* is not a priority as land is not used for provisioning. There is no drive to protect
1045 current agriculture

1046 4.4.3 *System restructuring – Retreat*

This policy direction aims to encourage population movement out of the more vulnerable parts of the delta. *Vulnerability* is reduced by significantly focusing on *financial* and *human* capital. This may include financial incentives to relocate outside of the delta and farmer investment in training for new non-delta livelihoods. *DRR* focuses on *post disaster recovery and rehabilitation*, specifically, the promotion of relocation outside of the delta following an event. *Ecosystem resilience* is not a priority as land is not used for provisioning. However, new habitats may be created as an incidental impact of the policy.

5. Discussion and conclusion

In this paper, we asked: what adaptations are currently occurring in deltas?; what are possible future directions for adaptation policy?; and, what are the trade-offs associated with each policy direction?

For the first time, we have generated a set of observed adaptations that are occurring in three distinct deltas, but which are also generalizable across deltas worldwide. Adaptations are grouped around three main objectives: (1) actions to reduce socio-economic vulnerability; (2) actions that address disaster risk reduction; and (3) actions that affect social-ecological resilience. In this analysis, we do not reflect on the ‘success’, ‘failure’ or ‘desirability’ of the adaptations, but simply identify what is happening. However, this raises an important research question: what are the short-term and long-term impacts of these adaptations on households and the wider delta? And, are adaptations that we are observing today suitable for the future when climatic and other conditions may be very different? Understanding these questions is recommended for future research and DECCMA will also try to provide a quantitative answer.

Adaptation actions rarely occur in isolation. More often packages of adaptation measures developed, implemented and evaluated in response to different needs and priorities of nations { ADDIN EN.CITE <EndNote><Cite ExcludeAuth="1"><Author>European Environment Agency

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 location>Luxembourg: Publications Office of the European Union</pub-
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 of adaptations are likely to reflect policymakers' commitment to both investment and significant
 change. In this paper, we have developed a method to identify suites of adaptation policies. By
 recognising both the drivers and constraints on the development of policy (levels of investment and
 political will to implement change), we have been able to define seven alternative sets of adaptation
 policy choices that cover a range of possible future states in many deltas. These seven futures also
 make explicit the trade-offs that occur when policymakers prioritise different aspects of adaptation.
 As with any work that attempts to identify plausible and realistic bundles of future choices, this
 research is constrained by current thinking about the nature and scope of adaptation present in
 deltas today. Indeed, by basing the future policy directions on current and planned adaptation
 choices we limit the adaptation set to what is known. However, we start to move beyond this by
 exploring what transformative adaptation might look like in deltas. As a next step in this research,
 these options can be taken to a range of delta stakeholders combined with other analysis of the
 future. This will promote further insight on adaptation choices and their implications and refine the
 choices presented here. This includes application to specific deltas and comparison with the policy
 process where possible. For instance, the first Bangladesh Delta Plan 2100 (BDP2100) is under
 preparation and the draft is now in circulation for expert comments { ADDIN EN.CITE
 <EndNote><Cite ExcludeAuth="1"><Author>General Economics Division (GEC) of the Government of
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1097 Bangladesh</Author><Year>2017</Year><RecNum>687</RecNum><Prefix>GEC`,
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 1101 name="Report">27</ref-type><contributors><authors><author>General Economics Division (GEC)
 1102 of the Government of the People's Republic of
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 1106 [content/uploads/2017/delta_plan/Bangladesh_Delta_Plan_2100_DRAFT.pdf](http://www.plancomm.gov.bd/wp-content/uploads/2017/delta_plan/Bangladesh_Delta_Plan_2100_DRAFT.pdf). Last accessed 18
 1107 January 2018</pub-location><urls></urls></record></Cite></EndNote>}. As a living plan, the
 1108 methods described here can potentially provide a reflective approach to develop the BDP2100 into
 1109 the future.

1110 In answering these questions, we are able to reflect on the implications of adaptation policy choices
 1111 for deltas where there are uncertain future socio-economic development trajectories, to support
 1112 policymakers' decisions on the trade-offs necessary to follow their normative goals. This method
 1113 represents a possible way forward for the global stocktake of adaptation under the Paris Agreement,
 1114 as it identifies an approach to documenting observed adaptation, as well as giving a vision of
 1115 possible sets of future adaptation options. Instead of providing a silver bullet this is a way that
 1116 countries can consider adaptation in a way that suits their geopolitical context and can address their
 1117 normative goals, expressed as their development aspirations.

Table 4: Adaptation interventions under the minimum intervention direction

Broad objective of adaptation	Adaptation class	Example of adaptation intervention
Addressing drivers of vulnerability	1. Financial capital	<i>Not a priority / component not active</i>
	2. Human capital	<ul style="list-style-type: none"> Agricultural extension officer who provide basic training on how to increase income at the household level, such as learning new farming or fishing techniques.
	3. Social capital	<i>Not a priority / component not active</i>
	4. Natural capital	<i>Not a priority / component not active</i>
	5. Physical capital	<i>Not a priority / component not active</i>
DRR	6. Managing long term risk	<ul style="list-style-type: none"> Ensure food availability during flood (e.g. Floating gardens and hanging vegetable garden)
	7. Preparedness	<i>Not a priority / component not active</i>
	8. Response	<ul style="list-style-type: none"> Temporary evacuation Use of emergency responders Secondment of army or national resources
	9. Post disaster recovery and rehabilitation	<ul style="list-style-type: none"> Post disaster mobile water treatment plants Post disaster house construction
Landscape/ ecosystem resilience	10. Provisioning	<ul style="list-style-type: none"> Potable water management
	11. Regulating	<i>Not a priority / component not active</i>
	12. Habitat	<i>Not a priority / component not active</i>
	13. Cultural	<i>Not a priority / component not active</i>

Table 5: Adaptation interventions under the capacity expansion direction

Broad objective of adaptation	Adaptation class	Example of adaptation intervention
Addressing drivers of vulnerability	1. Financial capital	<ul style="list-style-type: none"> Promote private sector investments in eco-tourism through economic incentives Post-harvest production and storage Develop and use open spaces, green belts and other ecologically sensitive areas for alternative livelihood such as urban farming Existence of loans at government level Incentives for migration to economic expansion areas
	2. Human capital	<ul style="list-style-type: none"> Education for non-farm livelihoods, based within the delta (e.g. STEM livelihoods) Education for non-farm livelihoods, based outside the delta (e.g. STEM livelihoods)
	3. Social capital	<i>Not a priority / component not active</i>
	4. Natural capital	<i>Not a priority / component not active</i>
	5. Physical capital	<ul style="list-style-type: none"> Access to markets for all, including infrastructure, training
DRR	6. Managing long term risk	<ul style="list-style-type: none"> Government funds to reduce risks to agriculture (Government run Agriculture Disaster Mitigation Fund) Establish agriculture and fisheries based insurance schemes Cyclone/flood shelters, including early warning systems River/coastal management defence infrastructure(including sea walls, groynes, dikes and polders) Climate proof grain silos/storage Ensure food availability during flood (e.g. Floating gardens and hanging vegetable garden)
	7. Preparedness	<ul style="list-style-type: none"> Maintain existing infrastructure (e.g., coastal embankments, river embankments and drainage systems, urban drainage systems)
	8. Response	<ul style="list-style-type: none"> Emergency aid provision Provision to ensure business and economic activities that support the economy receive immediate attention Critical infrastructure protection
	9. Post disaster recovery and rehabilitation	<ul style="list-style-type: none"> Initiatives to get the economy running quickly, e.g. funds available to rebuild damaged economic resources such as ports, roads and grain stores
Landscape/ecosystem	10.Provisioning	<ul style="list-style-type: none"> Potable water management

resilience		<ul style="list-style-type: none"> • Climate tolerant crops (Saline tolerant crops; Use of drought and heat resistant crop varieties – e.g. drought tolerant peppers) • Using different crop varieties • Climate tolerant aquaculture • Promote saline tolerant trees to prevent erosion around farms and homes • Seed bank for crop diversification • Alternative climate proof grasses for cattle
	11.Regulating	<ul style="list-style-type: none"> • Use of agro-chemicals • Create incentives for investor in tree crops and plantation (tax relief for private sector investment in research and development)
	12.Habitat	<i>Not a priority / component not active</i>
	13.Cultural	<i>Not a priority / component not active</i>

Table 6: Adaptation interventions under the efficiency enhancement direction

Broad objective of adaptation	Adaptation class	Example of adaptation intervention
Addressing drivers of vulnerability	1. Financial capital	<i>Not a priority / component not active</i>
	2. Human capital	<ul style="list-style-type: none"> • Use of climate resilient farming techniques • Livelihood diversification (farming) • Livelihood diversification (fishing) • Livelihood diversification - off-farm activity • Post-harvest production and storage at local level (e.g. farmer led)
	3. Social capital	<ul style="list-style-type: none"> • Farmer led cooperatives that reduce the cost of production/distribution
	4. Natural capital	<ul style="list-style-type: none"> • Fishing zones/rights for small-scale fishers
	5. Physical capital	<i>Not a priority / component not active</i>
DRR	6. Managing long term risk	<ul style="list-style-type: none"> • Cyclone/flood shelters, including early warning systems • All-Risk-changing-modifications to homes (walls/floors, etc.) - through funding and new building codes • Rehabilitation and upgrading of reservoirs for water (e.g. dredging, raising spillway levels) • Government funds to reduce risks to agriculture (Government run Agriculture Disaster Mitigation Fund) • Ensure food availability during flood (e.g. Floating gardens and hanging vegetable garden) • Land zoning/ no build zones
	7. Preparedness	<ul style="list-style-type: none"> • Education at school level re. responsiveness for DRR management e.g. evacuation training • Active stakeholder engagement in design and delivery of DRR • Communication and information re. individual roles and responsibilities re DRR • Readiness of emergency services to distribute medicines, food and potable water
	8. Response	<i>Not a priority / component not active</i>
	9. Post disaster recovery and rehabilitation	<i>Not a priority / component not active</i>
Landscape/ecosystem resilience	10.Provisioning	<ul style="list-style-type: none"> • Mixed land use (e.g. polder and shrimp farm with rice) • Changing irrigation and water level management practices to improve agriculture

	11.Regulating	<ul style="list-style-type: none"> • Mangrove forest planting • Promote the adoption of farm forestry practices, which include managing trees on farms, farm boundary planting and agroforestry systems (Ghana) • Promote ecological restoration of degraded and poorly stocked forests using appropriate reforestation/restoration techniques(ie enrichment planting, Assisted Natural Regeneration) • Tree planting in public areas • Reduce the pressure on forests for wood-fuels by encouraging use of renewable energy • Afforestation – climate tolerant bamboo
	12.Habitat	<ul style="list-style-type: none"> • Create biological corridors between existing of conservation areas to maintain gene flows • Promote establishment of protected green spaces with native grass along waterways
	13.Cultural	<ul style="list-style-type: none"> • Conservation of wildlife and biodiversity in natural heritage sites including sacred groves, protected areas • Protect sacred groves

Table 7: Adaptation interventions under the system restructuring direction

Broad objective of adaptation	Adaptation class	Example of adaptation intervention		
		Protect	Accommodate	Retreat
Addressing drivers of vulnerability	1. Financial capital	<ul style="list-style-type: none"> Develop and use open spaces, green belts and other ecologically sensitive areas for farming 	<ul style="list-style-type: none"> Promote private sector investments in eco-tourism through economic incentives Development of non-farm industry 	<ul style="list-style-type: none"> Financial incentives to relocate outside of the delta
	2. Human capital	<ul style="list-style-type: none"> Use of climate resilient farming techniques 	<ul style="list-style-type: none"> Education for non-farm livelihoods, based within the delta 	<ul style="list-style-type: none"> Education for non-farm livelihoods, based outside the delta
	3. Social capital	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>
	4. Natural capital	<ul style="list-style-type: none"> Land redistribution (to the poor or other groups) Fishing zones/rights for small-scale fishers 	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>
	5. Physical capital	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>
DRR	6. Managing long term risk	<ul style="list-style-type: none"> Raise land using controlled sedimentation Beach nourishment Land zoning, including no build zones River/coastal management defence infrastructure (including sea walls, groynes, dikes) 	<ul style="list-style-type: none"> Cyclone/flood shelters, including early warning systems Train community in DRR management Train community in water management All-Risk-changing-modifications to homes (e.g., height of 	<i>Not a priority / component not active</i>

		and polders)	foundations/walls/floors , climate resilient cluster housing) and local facilities (e.g., raise water sources and sanitation facilities above flood levels) through funding, loans and new building standards and codes	
	7. Preparedness	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>
	8. Response	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>
	9. Post disaster recovery and rehabilitation	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>	<ul style="list-style-type: none"> • Example absent from the data but could include government supported relocation of people outside the delta following an event
Landscape/ecosystem resilience	10. Provisioning	<ul style="list-style-type: none"> • Mixed land use (e.g. polder and shrimp farm with rice) • Changing irrigation and water level management practices to improve agriculture • Climate tolerant crops (Saline tolerant crops; 	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>

		Use of drought and heat resistant crop varieties – e.g. drought tolerant peppers) <ul style="list-style-type: none"> • Using different crop varieties • Climate tolerant aquaculture 		
	11. Regulating	<ul style="list-style-type: none"> • River course management • Reduce the pressure on forests for wood-fuels by encouraging use of renewable energy • No commercial mining in forested areas 	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>
	12. Habitat	<i>Not a priority / component not active</i>	<i>Not a priority / component not active (although new habitat may be created)</i>	<i>Not a priority / component not active(although new habitat may be created)</i>
	13. Cultural	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>	<i>Not a priority / component not active</i>

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